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Le programme d'études inductif s'inspire principalement des théories fonctionnelles ou communicatives du langage. Dans cette approche, les élèves intègrent différentes matières par la résolution de problèmes significatifs pour eux. Chaque étudiant utilise alors ses connaissances afin d'apporter ou d'acquérir les habiletés nécessaires à la résolution du problème. Les élèves sont évalués sur les habiletés apprises et leur niveau de compréhension. Il existe deux versions de chaque ensemble de problèmes : la version descriptive présentée aux étudiants et le guide de l'enseignant. Ce dernier contient entre autres une description de l'ensemble du problème, les habiletés concernées, les solutions et des suggestions d'évaluation. L'auteure illustre son approche à l'aide d'un exemple en mathématiques destiné à des élèves de 7e et 8e années. Elle présente une version abrégée, la version des élèves et une discussion comprenant en partie le guide de l'enseignant.

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CENTRE INTERDISCIPLINAIRE DE RECHERCHE SUR L'APPRENTISSAGE ET LE DÉVELOPPEMENT EN ÉDUCATION

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Université du Québec à Montréal

The Inductive Curriculum: Integrated Teaching and Learning for the Middle School

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There is a sense of crisis in science education and a feeling that mathematics teaching is languishing in doldrums going back to the turn of the century[1]. There is concern at all levels, and certainly in the middle school grades 7 and 8, perhaps 9. These years have always been difficult, and many organizational arrangements and curriculums have been tried. Contributing to the malaise is a growing recognition that achievement testing contributes little or nothing to the improvement of teaching and learning. The student evaluations that do guide teaching are carried out with varying degrees of success by individual teachers, who receive little or no help or training in evaluation (McLean, 1985; Buggins, 1985). Assessments of achievement tell us there are problems but give few hints as to what should be done.

National and international surveys of mathematics achievement have shown that about half the students in North America are still not able to do simple percentage problems by the end of grade 8.[2] about a third to one-half fail at numerical operations more complex than simple addition and subtraction, and the success rate is rarely as high as 50 percent on any but the simplest word problems (McLean, 1982; McKnight et al., 1987; McLean, Wolfe, & Wahlstrom, 1987). The shortcomings are not unique to the middle schools, of course: one study in the USA found no teaching at all of applications involving percents by 34 Grade 4 and 5 teachers in 17 schools (Porter, 1986). This performance bodes ill for science and mathematics in the secondary school and falls short of that needed in a modern technological society. There is plenty of room for improvement.

The present paper describes an approach designed to replace the abstract, rule-driven structures by meaningful, practical problem solving in a way that integrates language arts with other subjects, including mathematics and science. The inductive curriculum has roots going back to Locke, Rousseau and Dewey (Swartz, 1985), but it owes its present inspiration to communicative, or functional language theories and their implications for teaching and testing (Hymes, 1964; Canale & Swain, 1980; Gorman, 1986). The teaching approach has been shaped by developments in language teaching, but there has also been extensive borrowing from three current streams in educational research and development, ial cognitive science, especially situated cognition (Brown,

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[1]Crisis in science: (Duschl, 1985; Science Council, 1984); doldrums in match: (Crawford, 1970; Sirotnik, 1983); international studies: (McLean, Wolfe, & Wahlstrom, 1987; McKnight et al., 1987); "national" studies: (McLean, 1982; Connelly, Crocker, & Kass, 1985).

[2]On nine ratio and proportion items in the international survey, an average of 42 per cent of Ontario students answered correctly at the beginning of the year and 50 per cent at the end. On eight items covering percent, the percentages correct were 36 and 49. A province-wide survey in 1981 revealed only a little more growth through Grade 10.

Collins and Duguid, 1989) and metacognition (Schoenfeld, 1985; Haller, Child and Walberg, 1988); (h) social psychology, especially cooperative learning in small groups (Johnson, Johnson & Maruyama, 1983; Deutsch, 1985; Wettersten, 1987; Slavin, 1983); and (i) educational evaluation, especially evaluation of student achievement by means of portfolios, sometimes called records of achievement (Broadfoot, 1988; Hargreaves, et al., 1988).

Language Theories

The essential ideas for the inductive curriculum emerged from study of the work of those who have reformed language teaching and testing over the past decade (Thornton, 1986). The reforms in language teaching are based on *functional*, or *communicative* theories of language; theories that emphasize the purpose of language and the primacy of communication in context. These stand in opposition to *structural* theories that imply frameworks for language (and science and mathematics) that stand independent of purpose and context.

Mathematics and science curriculums are not usually analyzed from this perspective, but the formalism and universality claimed for them put them firmly in the structuralist camp. The authors of one study decried the lack of reference to the role of science in society, and technology in particular, and dubbed the approach "textbook science" (Science Council, 1984, p. 37). Others have documented how "teachers rarely or never addressed the noncontent components of science in their presentations and academic work assignments" (Millman, 1987, p. 611).

Language teaching, both first language and other languages, reached a crisis in North America about twenty-five years ago, especially in what were then commonly called *foreign languages*. It was no longer adequate just to be able to read other languages; people wanted to be able to communicate--to speak with others and to understand what they said. There was also a realisation, still unfolding, that too many students were not even learning their own first language well by being taught and drilled on its structure. Teaching rules and their application left many students with poor communication skills, especially in writing. One survey suggested that perhaps 25 percent of adults (almost all with more than eight years of schooling) are functionally illiterate (Creative Research Group, 1987). The key that unlocked new and promising teaching approaches was the recognition of the primacy of meaning--structure had to be made the servant of meaning rather than the master.

Meaning, however, is not a fixed feature just waiting to be discovered. Instead, meaning is continually created as individuals interact with their environment[3]. This view of meaning revealed daunting complexities for language teaching and testing because language therefore has meaning only in context, and context includes knowledge, past experience, manners and mores and more.

The dependence of meaning on context presents a special challenge to the definition and measurement of school achievement. If achievement means communication, then every task set to examine someone's ability to communicate, to get the meaning across, has to provide a context. To be complete, tasks must specify who is communicating with whom, under what circumstances, for what purpose. Knowledge of the gender as well as the relative age and status of the participants is sometimes necessary if one is to choose the most appropriate form of communication. The idea that achievement is context dependent in this complex way is still not understood and accepted by many in the measurement community, but language teachers know it (Gorman, 1986; McLean & Goldstein, 1988). There are fascinating parallels between developing paradigms in language and in science (Weaver, 1985), and a growing awareness of the importance of language to mathematical understanding (Jolle and Fuxman, 1989).

The Inductive Curriculum

The initial objective of the inductive curriculum was to implement *functional* theories for the teaching of mathematics and science in ways similar to those that are shaping teaching and testing in language arts. These theories also provide a definition of achievement from which assessment teachniques can be derived and defended. As development proceeded, it became clear that any such implementation would have to involve the use of language to such an extent that integration of language arts with mathematics and science was a natural and desirable outcome. Such integration was therefore attempted in a more conscious and systematic way. Attention is given to official guideline topics (energy, light, geometry, ...), but they are tucked anonymously inside sets of meaningful problems. To emphasize function and purpose, the problem sets are given names such as, *Making Sense of Opinion Polls* and *The Community Centre Gets a Pool*. Research, now backed by experience, suggest that more students, especially in the middle school, will learn mathematics and science skills and concepts

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[3]The ideas on which this recognition was based were formulated in Europe before the turn of the century, but even though he elements were set out in English before World War II, it was some time before they affected teaching in North America (Rosenblatt, 1938).

by working on problems meaningful to them, problems in which they see a purpose for the skills and concepts. Meaningful problems offer natural ways to integrate language arts with science, mathematics and social studies.

In the inductive curriculum, students work cooperatively with the teacher, in pairs or in small groups. The objective is for all students to bring their background knowledge to bear and to learn the new skills and approaches necessary to solve the problems.[4] Since the objective is for all students to learn the skills, individuals will be set their own problems at an appropriate time in order to evaluate their skill and understanding. Functional curriculums lend themselves best to evaluation via systematic cumulative records of performance, e.g. folders of work completed and marked by the student, the teacher and other students. Each such folder is unique for every student, but samples of content at several levels of performance must be established for marking so that standards are understood. We now turn to the examples.

Problem Sets

A review of mathematics and science textbooks reveals some creative and challenging exercises and problems--as well as many contrived and meaningless ones. The common feature, however, is the lack of a meaningful context--most entirely lack a real context. Two examples are given in Figure 0-1, neither especially good nor especially bad illustrations.

Figure 0-1: Exercises reproduced from Grade 7 or 8 mathematics textbooks to illustrate neutral or absent context and purpose.*

An airplane is flying at 1760 m represented by + 1760 above sea level. A submarine is 185 m represented by - 185 below the water surface. What is the distance between the airplane and the submarine?

Starting at 6 a.m., two buses leave from the same stop. One downtown bus returns to the stop every 13 minutes, and the other bus returns every 18 minutes. Indicate the next two times that both buses leave this stop together.

*Curriculum Guide 1987, B.C. Mathematics, Grades 1-8.
Examples are taken from Grades 7 and 8.

[4] Some writers would limit the term *problem solving*, e.g. "A problem that holds no surprises in store and that can be solved comfortably by routine or familiar procedures... is an exercise".
(Schoenfeld, 1983). These authors might refer to many of the problems proposed here as *exercises*. We will continue to refer to them as *problem sets* and to the process of arriving at solutions as *problem solving*, inviting the readers to think of them as exercises if they wish.

This concern for context and meaning shares some elements with the concern expressed by the Science Council of Canada for a more authentic view of science (Science Council, 1984). The discussion is as relevant to mathematics as it is to science:

> The Science Council is concerned with the image of science conveyed by the science textbooks. Research has shown that "textbook science" tends to be overly standardized and simplified in order to present a smooth road to scientific knowledge. But if science itself is a search for explanation, then surely science education must give students an authentic explanation of the way science works. The Council acknowledges, in general, the accuracy of the scientific knowledge contained in textbooks and has received few complaints about that. The problem lies with the inadequate representation of the scientific enterprise and the consequences of this for students.
>
> A better portrait of science, we believe, should include the following aspects: the history of science and technology, an account of their relationship, and a reflection on the nature of scientific knowledge (p. 37).

The above is a concern for content, rather than format or method (which are dealt with in other parts of the report). It is often the contrived exercises, however, that are "overly standardized and simplified", since it is difficult to set such problems in a meaningful context. Meaningful problem sets can provide a few glimpses of the history of science and technology (and their relationship), but such content will have to be taught directly if a better, fuller portrait of science is to be presented.

The Science Council was also concerned about context, as in, "The Science Council believes that the science that is taught to young Canadians should be set in a Canadian context and that this context should include both historical and social aspects" (p. 40). This carries the idea of context one small step farther, since the suggestion is that the context be *explicitly* Canadian. It would be difficult to present meaningful problems without any "social aspect", but quite possible to omit the "historical aspects". If problems are to be relevant to the social realities of 12 and 13 year-olds, however, the settings of most problems have to be contemporary. Two sample problem sets are shown in the next section, focussing on percentages, geometry, estimation, language and social studies.

Each problem set treats one or more guideline topic (acids and bases, percent) but necessarily brings in a variety of skills and concepts. Problem sets create a forum for developing *criterial knowledge*, an understanding of what constitutes an interesting, meaningful problem (Perrett, 1986). The following are criteria problem sets must meet:

1. The context (setting) of the problems must be interesting, realistic and recognizable to students.

2. The mathematics or science content is generally useful and is central to the solution of the problems.

3. Some satisfying solutions are accessible reasonably quickly for the majority of the students, but there are extensions that challenge the more able students.

4. Other versions of the problems can be easily generated for practice and evaluation without boring repetition.

To make the discussion concrete, two problem sets will be presented. These were designed with mathematics content for Grade 7 or Grade 8, depending on the curriculum guide and on the previous experience of the students. As in language teaching, meaningful settings take time and space to set out, so the examples take up several pages. There are two versions of any set, (a) the descriptive version presented to the students, and (b) the teacher's guide, containing a brief narrative description of the problem set, the skills and concepts the set involves, prerequisite skills, suggested timing, specific presentation tactics, solutions to all the major parts of the set, and suggestions for evaluation. The brief narrative version will be presented first, then the students' version followed by discussion which will include much of what is included in the teacher's guide.

Making Sense From Opinion Polls

Purpose. To learn how language and numbers can interact to produce various meanings when people are asked what they think or what they will do.

Main foci. The vocabulary and question technique of opinion polling and the correct use of percentages to extract meaning from the raw results of polls.

Activities. Making sense of raw results obtained by others (choice, calculation, comparison and meaning of percentages), framing questions and statements and doing own survey(s), making sense of results of own survey(s), communicating the sense to others by words, graphs, charts and whatever.

Narrative description. Hardly a day passes without reports of some new survey of public opinion--"Who would make the best Prime Minister?", "If an election were held tomorrow, which party would you support?", "Should the legal age for drinking be raised?". One or two thousand people across Canada or across a province are carefully

chosen and asked their opinions--a "poll" is taken, hence the term "opinion poll", and reference to "polling" and "pollsters". When the government of the day does something, they are sometimes accused of "government by poll", and the results of private polls are "leaked" to the press. The way the questions or statements are phrased is crucial to the outcome, and the language used to report the results can suggest various meanings, depending on style and word choice. Careful attention to language *and* numbers is required to make sense of opinion polls.

Newspapers and magazines never give the raw results of polls (the numbers of people choosing the various alternatives), because no one can make sense of them. The numbers, the "frequencies", are converted to percentages because they can make sense; but except in the simplest cases, *students have to choose particular percentages* to make certain findings visible. Surprising challenges, and surprising results, are often encountered when we try to find out whether women answer differently from men, older people differently from younger and the like. The first problem in this set is an example of such a challenge--whether students in Grades 7, 8, 9 and 10 planned to continue through Grade 13 or stop sooner[5].

In addition to the constant attention to language, students apply ratio, proportion and percent with plenty of practice in estimating and using a calculator. Extensions to probability and statistics are available to challenge the best students right through high school and beyond, but there are many interesting results to be found by elementary means in the middle school.

Making Sense from Opinion Polls

Students' Version

Businesses such as *Canadian Facts* and *The Gallup Poll* make their money by predicting the future. They ask approximately a thousand people a few questions, and from their answers they predict how the rest of Canadians will vote and what they will buy. Choosing which people to ask and getting their replies is called *polling*, and the results are called *polls*, or *surveys*. How do they make the predictions? They use science, imagination and lots of simple calculations, but the real secret is in asking the right question and making sense of the replies.

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[5]The survey was conducted in 1983, when Ontario still had Grade 13.

A new poll is reported on television and in the newspapers nearly every day. Some are done just to find out what people are thinking about free trade, nuclear power or abortion, for example. A few years ago (when there was still Grade 13), the Ontario Institute for Studies in Education (OISE) took a poll of students across Ontario in Grades 7, 8, 9 and 10. Students were asked (among other things) about their plans for future schooling. The Ministry of Education wanted to know whether plans changed very much over those years. Only a few thousand were included in the poll, but they were carefully chosen to be as much like the whole Ontario Grade 7 to 10 group as possible.

Rather than ask a question, students were asked to choose one of three alternatives. The replies obtained in 1983 are summarized in Table 1. The alternatives were stated this way:

In the next few years, I plan to

a. complete Grade 13.
b. complete Grade 12, but not Grade 13.
c. leave school before completing Grade 12.

Problem One: Think of another way to ask students about these same plans. Change it to a question, and also think of a different way to phrase the question now that Grade 13 has been discontinued. Write out two different ways to get the information.

Problem Two: Refer to Table 1. We don't try to make sense of the counts, because the raw numbers are too awkward. It is good to look them over, however, and think over some questions before moving on. What do you make of the number of replies from each grade, for example? Is it reasonable for the total number of replies from Grade 9 to be smaller than from the other grades? What do you think when we tell you that the survey questionnaire was given to almost exactly the same number of Grade 9 and Grade 10 students? Why is it awkward to compare the counts from one grade with those of another? To get a feeling for the process, ask students in your own class about their plans (do it by "secret ballot"). Perhaps other classes would join the survey. Prepare your own tabulation.

Problem Three: As you say, along the right-hand edge of Table 1 are the total number of students who replied to the survey, in each grade. To become familiar with the numbers *and what they stand for*, check the totals by adding the numbers in each row. Then add the numbers in each column to see how many students planned to complete Grade 13, Grade 12 or leave before completing Grade 12. Find the number 264 in the table. Write out a sentence explaining what the number means. The total number of

replies from all grades was 3506. Add the column totals to verify this number (all these totals will be needed for the next problems). How else could you check the grand total?

Problem Four: One good way to make sense of polls such as this is to convert the counts to percentages. Take an easy example first--express the column totals at the bottom as a percentage of the grand total. This allows us to write something such as, "Sixty-three percent of students in Grades 7 to 10 said they plan to complete Grade 13. Only three percent planned to leave school before completing Grade 12". We can compare percentages so long as they are proportions of the same number (the grand total, in this example). Express the *grade* totals as a percentage of the grand total and write out a description how the total number of students who responded to the question were divided among the four grades. To find out whether plans change from grade to grade, we have to compare percentages who choose each answer *within each grade*. That is the next problem.

Problem Five: Since we want to compare grades, we work separately within each grade. Start with row one (Grade 7), and express each count in the row as a percentage of the row total (934). Do this for each of the four rows. (How can you quickly check your calculations?) Now study the percentages and see what meaning you can make of them. There is a startling result, which you may have suspected from the counts but which strikes the eyes when you look at the table of percentages. In each group, write out a paragraph describing what you see.

Table O-1

Numbers of Ontario Students in Grades 7, 8, 9 and 10
Who Chose Each Option in a Survey of Their Plans for Finishing High School

Grade	Complete Grade 13	Complete Grade 12 but not Grade 13	Leave School before completing Grade 12	Total
7	729	186	19	934
8	651	264	28	943
9	178	501	36	715
10	667	229	18	914

Teacher's Guide

Making Sense of Opinion Polls

By working on their own versions, students should first discover that making sense of opinion polls begins with the phrasing of the questions or statements used in the poll. Once the wording is decided and responses collected, the task is to decide what percentages to calculate and then to work out wording that will communicate the meaning of their percentages. If some students have difficulty with percentages, the others in their group should help them and be sure they understand.

There is useful practice with calculators, especially in how to use one or more memory locations to make the calculations more efficient, but students must understand that calculations are the means, not the end. The products of interest are the ways of asking for the information and the explanations of the results.

Results of a 1981 survey of Ontario students in Grades 7 to 10 are presented as the number of students giving various replies to a question asking whether they planned to finish high school. When particular percentages are calculated, as in Table 2, a surprising result is obvious among the Grade 9's.

Discussion of random sampling is probably unavoidable, at least at the intuitive level--the idea of using some chance process to arrive at a *representative* sample. It is suggested that students carry out their own survey in order to give them a better understanding of how such numbers are obtained, and this should lead to questions about the comparability of samples. If no one else raises it, you should do it during the reflection days. It is a golden opportunity to discuss the greater uncertainties associated with small samples, especially non-random ones.

Analysis and discussion of a current or recent poll (from newspapers, magazines,...) extends the art and provides reverse practice (if 1500 people were surveyed and 28 percent agreed, how many people is that?). Published surveys also provide an explicit estimate of sampling error, such as, "The results will be accurate within four points, 19 times out of 20". Canadian law now requires that such error estimates be part of every published account. This opens the way to discussion of probability if it suits class and teacher, but stick with percentages, comparison of percentages and the meaning of percentages until everyone is comfortable with them.

Table O-2

Frequencies from Table O-1
Converted to Percentages

Grade	Complete Grade 13	Complete Grade 12 but not Grade 13	Leave School before completing Grade 12	Total
7	78	21	1	100
8	69	28	3	100
9	25	70	5	100
10	73	25	2	100
Total	63	34	3	100

As mentioned, the results are presented in terms of number of students replying, in other words, in terms of the raw frequencies (Table 1). It is not possible to make good sense of such a table. The idea of the *proportion* of students giving the various replies is the key, leaving the question of which proportion will be most useful. That line of reasoning leads easily to percentage, as a more convenient number (and to discussion of rounding and rounding error).

We have already cut the story short by pointing out the interesting feature of this table—the remarkable reversal of percentages in columns one and two in the Grade 9 row, and the return to the overall pattern in Grade 10. Whereas roughly three-quarters of the students in other grades said they would finish Grade 13, only one quarter said that at the end of Grade 9. Students should figure this out for themselves, of course, and the problems ask for paragraph of explanation.[6]

Students in Grades 7 to 10 should have several plausible explanations for the result. It suggests that Grade 9 is a turbulent year for many young people, but that things get better for those who stay in school. They should also try the other obvious way of calculating the percentages, by columns, and perhaps the third way (as a percentage of

[6] The survey and a discussion of it are reported in McLean, Les (1982) *Willing But not Enthusiastic*. Available from the Ontario Government and OISE bookstores.

the grand total). Neither of these other ways gives a satisfactory (meaningful) result, and this is an important point. If the question is, "Does the grade a student is in tell us what sort of plans they have for the future?", then the percentages must be calculated by grade for each category of plans, that is, the percentages must sum to 100 for each grade (each row). Demonstrating this by trying other ways will give some purposeful practice.

Explaining why one way makes more sense than the others gets right to the heart of the meaning we can make of percentages. Here is the outline:

> Stating the question in reverse order is not realistic (plans predicting grade), since students can make their own plans but have little control over what grade they are in. The *direction* of prediction dictates which percentages should be calculated. To predict *plans from grade*, we have to compare Grade 7 plans with Grade 8 plans, but the different numbers of student replies in those grades make the frequencies non-comparable. Expressing each number in a row as a percentage of row (grade) total gives us the right numbers to compare. Some people call this *standardizing by grade*, since we express the numbers for each grade in a standard form. If we predict by grade, we have to standardize by grade.

Teachers who have had an opportunity to study probability can introduce it inductively in the context of such tables. Probability is an option rarely included in Grade 8 curriculums, but the calculations are elementary and the concepts intuitive if kept within a restricted, *meaningful* context. Considering the group of 3506 as a whole and considering only grade, the likelihood (odds, probability) of picking at random and getting a Grade 7 student is 934/3506, or 0.27, or 27 times in 100. The probability of picking a Grade 9 student, however, is only 0.20. The probability that a student will have said she or he planned to finish Grade 13 is 2325/3506, or 0.63, while the probability for finishing Grade 12 but not 13 is only 0.34. Motivate these seemingly useless observations by promising that they will give new insights into prediction. (If students notice that these things you call probabilities sum to one for plans and separately for grade, then so much the better. Do not point it out too quickly.)

Ask the students as homework to try to think of ways these probabilities can be used in prediction. Say that it might help to consider what it means for a student to be in one of the cells of the table--in the top left-and corner, for example. They may come up with nothing, but remember that learning problem formulation and clarification is an important goal of schooling. Someone may surprise you. By whatever route, get to the point that *solving hard problems is often a matter of solving a simpler version first*. For example, suppose you cannot predict plans from grade and are if you can do something with that. If plans do not depend on grade and the two can be treated independently, that is a simpler case. Now tell them that in this special case, they can

calculate the probability of two outcomes at once (for example, picking a Grade 7 student who also plans to finish Grade 13) by multiplying the separate probabilities, something they can show in general later in their career if need be.

A very small amount of calculation will show that Table 1 is not likely such a special case. Take that odd cell in the Grade 9 row, for example, the number planning to complete Grade 13 (178 students). If plans are not linked to grade, the probability of these two together would be the product of their probabilities, 0.63 0.20 = 0.13. In other words, if this is a simpler case, then we should find 13 percent of the students in that cell. But we find only 5 percent! There are discrepancies in just about every cell, suggesting that plans are linked with grade--they are not independent. Working with the probabilities gives us a systematic, objective way to show that the results of the survey cannot be explained so simply. Keen students can be put on to Chi-Square statistics and hypothesis testing, which will keep them out of trouble for a long time.

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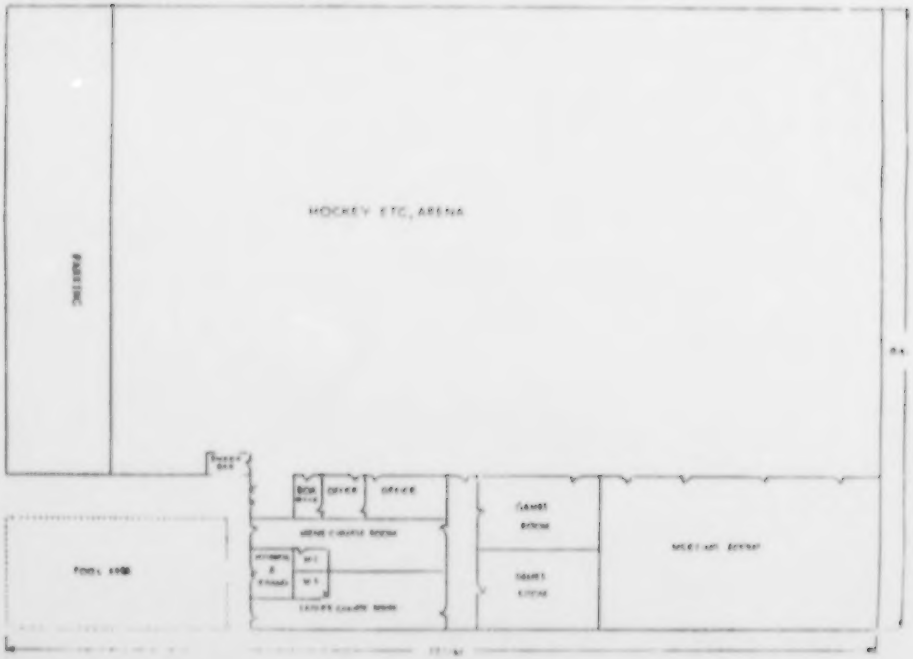

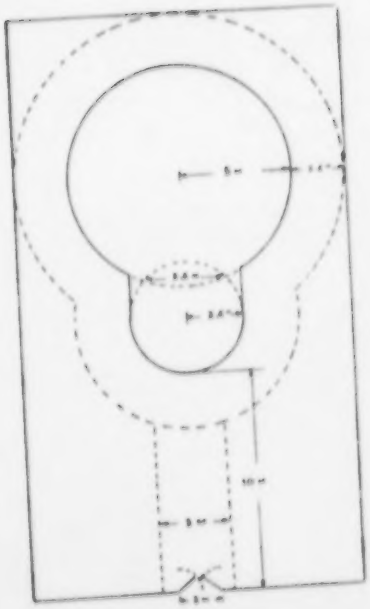

FIGURE 1 "METHUEN" SWIMMING POOL

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